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Patentanmeldung Nr. | Patent application No. | Demande de brevet n°

01301864.3

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
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THE HAGUE, 16/01/02
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Sheet 2 of the certificate
Page 2 de l'attestation

Anmeldung Nr.:
Application no.: 01301864.3
Demande n°:

Anmeldetag:
Date of filing: 01/03/01
Date de dépôt:

Anmelder:
Applicant(s):
Demandeur(s):
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Bezeichnung der Erfindung:
Title of the invention:
Titre de l'invention:
Mask and mask gripping device for a lithographic projection apparatus

In Anspruch genommene Prioriät(en) / Priority(ies) claimed / Priorité(s) revendiquée(s)

Staat: State: Pays:	Tag: Date: Date:	Aktenzeichen: File no. Numéro de dépôt:

Internationale Patentklassifikation:
International Patent classification:
Classification internationale des brevets:
G03F7/20

Am Anmeldetag benannte Vertragstaaten:
Contracting states designated at date of filing: AT/BE/CH/CY/DE/DK/ES/FI/FR/GB/GR/IE/IT/LI/LU/MC/NL/PT/SE/TR
Etats contractants désignés lors du depôt:

Bemerkungen:
Remarks:
Remarques:

See for original title of the application page 1 of the description.

Lithographic Projection mask, and Mask Gripping Device Therefor for use in a Lithographic Projection Apparatus

The present invention relates to a lithographic projection mask and a corresponding mask gripping device for use in a lithographic projection apparatus comprising:

a radiation system for supplying a projection beam of radiation;

a mask table for holding a mask on a mask bearing surface, the mask serving to pattern the projection beam according to a desired pattern;

a substrate table for holding a substrate; and

a projection system for projecting the patterned beam onto a target portion of the substrate.

Lithographic projection apparatus can be used, for example, in the manufacture of integrated circuits (ICs). In such a case, the patterning means may generate a circuit pattern corresponding to an individual layer of the IC, and this pattern can be imaged onto a target portion (*e.g.* comprising one or more dies) on a substrate (silicon wafer) that has been coated with a layer of radiation-sensitive material (resist). In general, a single wafer will contain a whole network of adjacent target portions that are successively irradiated via the projection system, one at a time. In current apparatus, employing patterning by a mask on a mask table, a distinction can be made between two different types of machine. In one type of lithographic projection apparatus, each target portion is irradiated by exposing the entire mask pattern onto the target portion in one go; such an apparatus is commonly referred to as a wafer stepper. In an alternative apparatus — commonly referred to as a step-and-scan apparatus — each target portion is irradiated by progressively scanning the mask pattern under the projection beam in a given reference direction (the "scanning" direction) while synchronously scanning the substrate table parallel or anti-parallel to this direction; since, in general, the projection system will have a magnification factor M (generally < 1), the speed V at which the substrate table is scanned will be a factor M times that at which the mask table is scanned. More information with

regard to lithographic devices as here described can be gleaned, for example, from US 6,046,792, incorporated herein by reference.

In a manufacturing process using a lithographic projection apparatus, a pattern (*e.g.* in a mask) is imaged onto a substrate that is at least partially covered by a layer of radiation-sensitive material (resist). Prior to this imaging step, the substrate may undergo various procedures, such as priming, resist coating and a soft bake. After exposure, the substrate may be subjected to other procedures, such as a post-exposure bake (PEB), development, a hard bake and measurement/inspection of the imaged features. This array of procedures is used as a basis to pattern an individual layer of a device, e.g. an IC. Such a patterned layer may then undergo various processes such as etching, ion-implantation (doping), metallization, oxidation, chemo-mechanical polishing, etc., all intended to finish off an individual layer. If several layers are required, then the whole procedure, or a variant thereof, will have to be repeated for each new layer. Eventually, an array of devices will be present on the substrate (wafer). These devices are then separated from one another by a technique such as dicing or sawing, whence the individual devices can be mounted on a carrier, connected to pins, etc. Further information regarding such processes can be obtained, for example, from the book "Microchip Fabrication: A Practical Guide to Semiconductor Processing", Third Edition, by Peter van Zant, McGraw Hill Publishing Co., 1997, ISBN 0-07-067250-4, incorporated herein by reference.

For the sake of simplicity, the projection system may hereinafter be referred to as the "lens"; however, this term should be broadly interpreted as encompassing various types of projection system, including refractive optics, reflective optics, and catadioptric systems, for example. The radiation system may also include components operating according to any of these design types for directing, shaping or controlling the projection beam of radiation, and such components may also be referred to below, collectively or singularly, as a "lens". Further, the lithographic apparatus may be of a type having two or more substrate tables (and/or two or more mask tables). In such "multiple stage" devices the additional tables may be used in parallel, or preparatory steps may be carried out on one or more tables while one or more other tables are being used for exposures. Twin stage lithographic apparatus are described, for example, in US 5,969,441 and WO 98/40791, both incorporated herein by reference.

The concept of a mask is well known in lithography, and it includes mask types such as binary, alternating phase-shift, and attenuated phase-shift, as well as various hybrid mask types. Placement of such a mask in the radiation beam causes selective transmission (in the case of a transmissive mask) or reflection (in the case of a reflective mask) of the radiation impinging on the mask, according to the pattern on the mask. The mask table ensures that the mask can be held at a desired position in the incoming radiation beam, and that it can be moved relative to the beam if so desired.

Conventionally, the mask table has been positioned such that radiation is passed from the illumination system through the mask, the projection system and onto the substrate. Such masks are known as transmissive masks since they selectively allow the radiation from the illumination system to pass through, thereby forming a pattern on the substrate. Such masks must be supported so as to allow the transmission of light therethrough. This has conventionally been achieved by using a vacuum in the table underneath a perimeter zone of the mask so that the atmospheric air pressure clamps the mask to the table.

In a lithographic apparatus the size of features that can be imaged onto the wafer is limited by the wavelength of the projection radiation. To produce integrated circuits with a higher density of devices, and hence higher operating speeds, it is desirable to be able to image smaller features. Whilst most current lithographic projection apparatus employ ultraviolet light generated by mercury lamps or excimer lasers, it has been proposed to use shorter wavelength radiation of around 13 nm. Such radiation is termed extreme ultraviolet (EUV) or soft x-ray and possible sources include laser-produced plasma sources, discharge sources or synchrotron radiation sources.

Since no materials are known to date to be sufficiently transparent to EUV radiation, a lithographic projection apparatus employing EUV radiation is envisaged to have a reflective mask. The size of the features to be imaged in EUV lithography makes the imaging process very sensitive to any contamination present on the mask. It is foreseen that any contaminant particles having a dimension in the order of 50 nm will result in defects present in devices fabricated in the substrate. Particle contamination on the pattern-bearing reflective surface of the mask should therefore be prevented.

Further, the reflective mask will generally be held at its backside on the mask table. Any contaminant particles present in between the backside of the mask and a

mask-bearing surface of the will result in irregularities of the reflective mask surface. Since the projection system will be non-telecentric on the object side (because a reflective mask is used), any irregularity in the surface figure of the reflective mask surface will translate into a local shift of the pattern imaged onto the substrate. Therefore, any particle contamination on the backside surface should also be prevented.

Conventionally, a mask is handled by a direct contact of a gripper on a mask surface. Both a mechanical gripper and a vacuum-operated gripper are used, a vacuum-operated gripper not being useful in the vacuum environment necessary for EUV lithography. Handling of the mask is required to bring a mask in the lithography tool from a storage box to for instance a mask library inside the lithography tool, and to bring a mask from the mask library to the mask table and *vice versa*.

The inventors have found that mechanical gripping contact will cause particles of various sizes to become released from the gripping area. Microslip of the contacting surfaces seems a mean cause for such particle generation. Any mechanical contact on the pattern-bearing and backside surfaces, and also the circumferential surfaces, of the mask should therefore be prevented. It is further found by the inventors that any particles that become released due to mechanical contact will generally remain near the contact area

It is an object of the present invention to prevent particle contamination on the pattern-bearing and/or backside surfaces of the mask.

This and other objects are achieved according to the invention by a lithographic projection mask having a gripping arrangement provided on the circumference of the mask for gripping the mask at, and further by a mask gripping device for gripping the above mask, the mask gripping device comprising a gripper adapted to gripping the mask at the gripping arrangement provided around the mask.

Any particles that may be released due to a mechanical gripping contact will remain away from the mask surfaces on the gripping arrangement itself and thus not cause the problems associated with contaminated mask surfaces referred to above.

To substantially reduce any release of particles upon mechanical contact, surfaces of the gripping arrangement are preferably provided with grooves for cooperation

with pins of the gripping device. Such a configuration also provides a simple, yet very effective and accurate positioning of the mask on the gripping device. To this end the grooves are advantageously directed to a common (imaginary) point within, above or below the mask. Preferably the pins are provided with rounded surfaces for cooperation with the grooves. Those measures reduce microslip as a cause of particle generation.

In a preferred embodiment brackets are provided around the circumference of the mask so as to occupy a minimum of space. The grooves may be provided in top-side and bottom-side surfaces of those brackets.

The present invention also provides a mask handling device, a mask holding box and a lithographic projection apparatus, which all comprise the above mask gripping device.

Although specific reference may be made in this text to the use of the apparatus according to the invention in the manufacture of ICs, it should be explicitly understood that such an apparatus has many other possible applications. For example, it may be employed in the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, liquid-crystal display panels, thin-film magnetic heads, etc. The skilled artisan will appreciate that, in the context of such alternative applications, any use of the terms "reticle", "wafer" or "die" in this text should be considered as being replaced by the more general terms "mask", "substrate" and "target portion", respectively.

In the present document, the terms “radiation” and “beam” are used to encompass all types of electromagnetic radiation, including ultraviolet (UV) radiation (*e.g.* with a wavelength of 365, 248, 193, 157 or 126 nm) and extreme ultra-violet (EUV or XUV) radiation (*e.g.* having a wavelength in the range 5-20 nm), as well as particle beams, such as ion beams or electron beams.

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings, in which like reference numerals indicate like parts, and in which:

Figure 1 depicts a lithographic projection apparatus according to an embodiment of the invention;

Figure 2 depicts a mask according to an embodiment of the invention;

Figure 3 depicts a detail of figure 2 and part of a mask gripping device according to the invention; and

Figure 4 depicts another embodiment of a pin of the mask gripping device of figure 3.

Figure 1 schematically depicts a lithographic projection apparatus 1 according to the present invention. The apparatus comprises:

a radiation system LA, IL for supplying a projection beam PB of EUV radiation;

a first object table (mask table) MT for holding a mask MA (*e.g.* a reticle), and connected to first positioning means PM for accurately positioning the mask with respect to item PL;

a second object table (substrate table) WT for holding a substrate W (*e.g.* a resist-coated silicon wafer), and connected to second positioning means PW for accurately positioning the substrate with respect to item PL;

a projection system ("lens") PL for imaging an irradiated portion of the mask MA onto a target portion C (die) of the substrate W. As here depicted, the projection system is of a reflective type.

The source LA (*e.g.* a laser-produced plasma source, a discharge source, or an undulator or wiggler provided around the path of an electron beam in a storage ring or synchrotron) produces a beam of EUV radiation. This beam is fed into an illumination system (illuminator) IL, either directly or after having traversed conditioning means, such as a beam expander, for example. The illuminator IL may comprise adjusting means for setting the outer and/or inner radial extent (commonly referred to as σ-outer and σ-inner, respectively) of the intensity distribution in the beam. In addition, it will generally comprise various other components, such as an integrator and a condenser. In this way, the beam PB impinging on the mask MA has a desired uniformity and intensity distribution in its cross-section.

It should be noted with regard to Figure 1 that the source LA may be within the housing of the lithographic projection apparatus, but that it may also be remote from the lithographic projection apparatus, the radiation beam which it produces being led into

the apparatus (*e.g.* with the aid of suitable directing mirrors). The current invention and claims encompass both of these scenarios.

The beam PB subsequently intercepts the mask MA, which is held on a mask table MT. Having been selectively reflected by the mask MA, the beam PB passes through the lens PL, which focuses the beam PB onto a target portion C of the substrate W. With the aid of the second positioning means (and interferometric measuring means IF), the substrate table WT can be moved accurately, *e.g.* so as to position different target portions C in the path of the beam PB. Similarly, the first positioning means can be used to accurately position the mask MA with respect to the path of the beam PB, *e.g.* after mechanical retrieval of the mask MA from a mask library or during a scan. In general, movement of the object tables MT, WT will be realized with the aid of a long-stroke module (course positioning) and a short-stroke module (fine positioning), which are not explicitly depicted in Figure 1.

The depicted apparatus can be used in two different modes:

1. In step mode, the mask table MT is kept essentially stationary, and an entire mask image is projected in one go (*i.e.* a single "flash") onto a target portion C. The substrate table WT is then shifted in the x and/or y directions so that a different target portion C can be irradiated by the beam PB;

2. In scan mode, essentially the same scenario applies, except that a given target portion C is not exposed in a single "flash". Instead, the mask table MT is movable in a given direction (the so-called "scan direction", *e.g.* the y direction) with a speed v, so that the projection beam PB is caused to scan over a mask image; concurrently, the substrate table WT is simultaneously moved in the same or opposite direction at a speed $V = Mv$, in which M is the magnification of the lens PL (typically, $M = 1/4$ or $1/5$). In this manner, a relatively large target portion C can be exposed, without having to compromise on resolution.

Figure 2 shows mask MA for use in the lithographic apparatus of figure 1. The mask is provided with a mask gripping arrangement taking the form of three brackets 10 attached to the circumference of the mask to grip the mask at for holding and handling the mask. The brackets may be attached by any suitable means to the mask and are in the present embodiment attached using a vacuum-compatible glue such as an

epoxy-based glue. However, brackets 10, or the gripping arrangement in general, may also constitute an integral part of the mask.

The location of the brackets on the mask has been chosen such as is convenient for handling the mask by mask manufacturers and mask users. They all will have their demands on the space around the mask that is available to arrange the brackets for their purposes. Further, the brackets are shown to be U-shaped in figures 2 and 3.

As can better be seen in figure 3, the brackets are provided with grooves 11a, 11b in the top-side and bottom-side surfaces, respectively, that are substantially in line with the pattern-bearing and backside surfaces of the mask. The grooves are directed to an imaginary point O that substantially coincides with a center point on a respective surface of the mask mask. In alternative embodiments such an imaginary point may be located within, below or above the mask in a space enclosed by the brackets, the grooves making an angle with the surfaces of the mask in such a configuration.

Figure 3 also shows part of a mask gripping device 20 for gripping mask MA in a mask handling part of the lithographic apparatus shown in figure 1. Device 20 comprises three pins 21b that are positioned on the device such that they can cooperate with three associated grooves provided in the three brackets of the above mask. It is seen that each pin 21b is provided with a boll 22b at its top. When the mask is held by gravity on the boll pins of the gripping device, the pins will be partially inserted into grooves 11b. Since the grooves are directed to a common point O, this results in a simple, but very effective and accurate kinematic positioning of the mask with respect to the gripping device. Since the configuration allows the mask to be accurately positioned on the gripping device, such a device 20 present in the handling system for masks or in a box for containing a mask can be made very simple, saving costs and improving reliability. Further, such a configuration of grooves and (boll) pins for gripping the mask provides a minimum of microslip, which is a cause of particle generation by mechanical contact. The rounded surface presented by the boll provided on the pin proves to be advantageous in this respect.

When handling the mask with the above gripping device, the mask remains fixed on the gripping device by partial insertion of the pins in associated grooves provided in the brackets due to gravity. The mask may then be handled using some acceleration

forces. The fixation of the mask on the gripping device under acceleration and deceleration forces will be increased by providing grooves that are directed to a common imaginary point located below or above the mask, as discussed above.

To improve safety, a safety arrangement as shown in figure 4 may be provided. The arrangement consisting of three upwards projecting pins 23 partially encloses a bracket of the mask when positioned on the gripping device, but does not make contact with the bracket, leaving a space between the bracket and the safety arrangement. Such a configuration will prevent the mask from falling off of the gripping device in emergency situations.

To further improve holding of the mask on the gripping device, such as, for instance, in a mask holding box for storing a mask, further pins 21a may be provided above the brackets for insertion in associated grooves in top-side surfaces of the brackets. This is shown in phantom figure 3. Pins 21a, 21b should still be lowered and lifted, respectively, as shown in figure 3 to grip the mask.

The mask gripping device disclosed as a part of the lithographic projection apparatus of figure 1 may also be a part of other tools, such as a mask writing apparatus, a mask cleaning apparatus, or a mask inspection apparatus.

Whilst we have described above specific embodiments of the invention, it will be appreciated that the invention may be practiced otherwise than as described. The description is not intended to limit the invention.

CLAIMS

1. A lithographic projection mask having a gripping arrangement provided on the circumference of the mask for gripping the mask at.

2. The mask according to claim 1, wherein the gripping arrangement comprises a surface having a surface normal that is oriented substantially parallel to a front side surface of the mask, and wherein a recess is provided in said surface, the recess being adapted for cooperation with a gripping surface of a gripper for the mask.

3. The mask according to claim 2, wherein the gripping arrangement comprises a first surface having a surface normal that is oriented substantially in a direction of a surface normal on the front side surface of the mask, and wherein the recess is provided in said first surface.

4. The mask according to claim 2 or 3, wherein the gripping arrangement comprises a second surface having a surface normal that is oriented substantially in a direction opposite to a direction of a surface normal on the front side surface of the mask, and wherein the recess is provided in said second surface.

5. The mask according to claim 2, 3 or 4, wherein a multiple of recesses is provided in said surface, the recesses comprising a grooves that are substantially oriented towards an imaginary point comprised in a space substantially enclosed by the arrangement.

6. The mask according to claim 5, wherein the imaginary point is substantially comprised within the mask.

7. The mask according to claim 6, wherein the imaginary point substantially coincides with a center point of the mask.

8. The mask according to claim 5, 6 or 7, wherein three grooves are provided, the grooves being positioned at intervals of substantially 120° around the mask.

9. The mask according to any one of the preceding claims, wherein the gripping arrangement comprises brackets.

10. The mask according to any one of the preceding claims, wherein the mask is a reflective mask.

11. A mask gripping device for gripping the mask according to claim 1, the mask gripping device comprising a gripper adapted to gripping the mask at the gripping arrangement provided around the mask.

12. The device according to claim 11, wherein the gripper comprises a pin for cooperation with a recess provided in a surface of the gripping arrangement of the mask so as to hold the mask in a direction substantially along the pins.

13. The device according to claim 12, wherein the pin comprises a rounded gripping surface for cooperation with the recess.

14. The device according to claim 13, wherein the pin comprises a boll for cooperation with the recess.

15. The device according to any one of claims 12 to 14, wherein the gripper comprise substantially opposing pins for cooperation with opposing recesses provided in surfaces of the gripping arrangement.

16. The device according to any one of claims 12 to 15, wherein the gripping arrangement of the mask comprises brackets, and wherein the gripper comprise an arrangement for at least partially enclosing a bracket when the mask is held on the pin so as to leave a space between the arrangement and its associated bracket.

17. A mask handling device for handling a mask according to claim 1, the device comprising a mask gripping device according to any one of claims 11 to 16.

18. A lithographic projection apparatus comprising:

a radiation system for providing a projection beam of radiation;

a mask table for holding a mask, the mask serving to pattern the projection beam according to a desired pattern;

a substrate table for holding a substrate;

a projection system for projecting the patterned beam onto a target portion of the substrate; and

a mask handling device for handling a mask according to claim 1, the device comprising a mask gripping device according to any one of claims 11 to 16.

19. The apparatus according to claim 18, wherein the radiation system comprises a radiation source.

20. The apparatus according to claim 18 or 19, wherein the radiation system provides a projection beam of EUV radiation having a wavelength in the range from 5 to 50 nm, especially 8 to 16 nm.

21. A mask holding box for containing a mask according to claim 1, the box comprising a mask gripping device according to any one of claims 11 to 16.

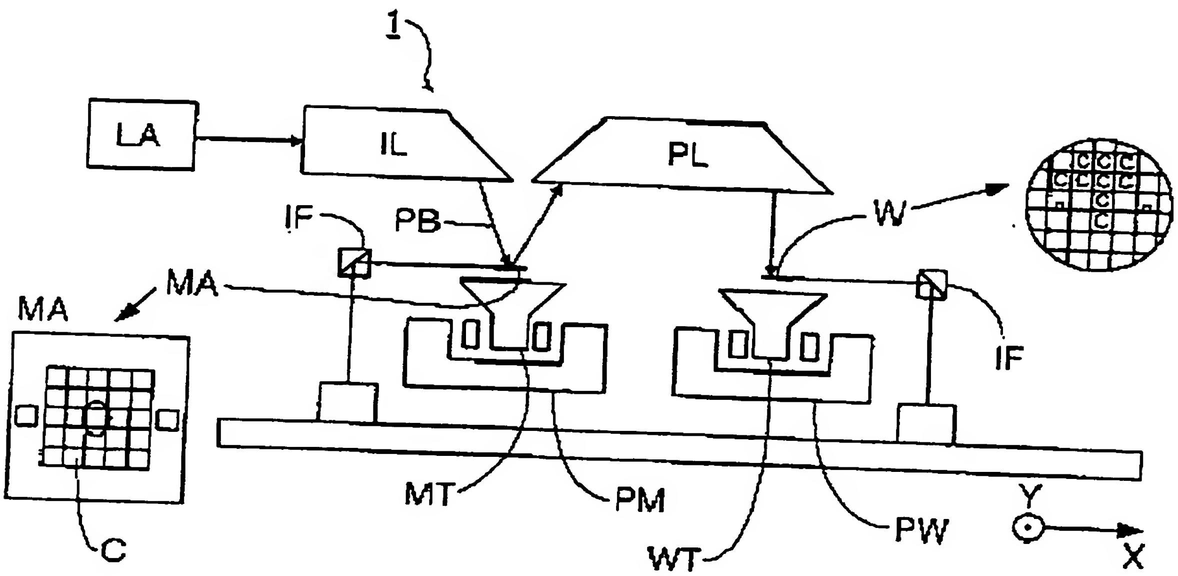

Fig. 1

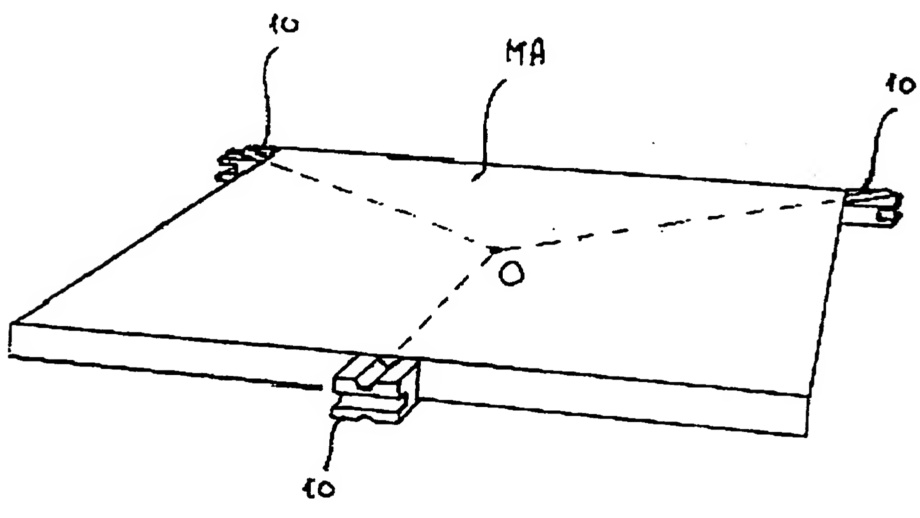

Fig. 2

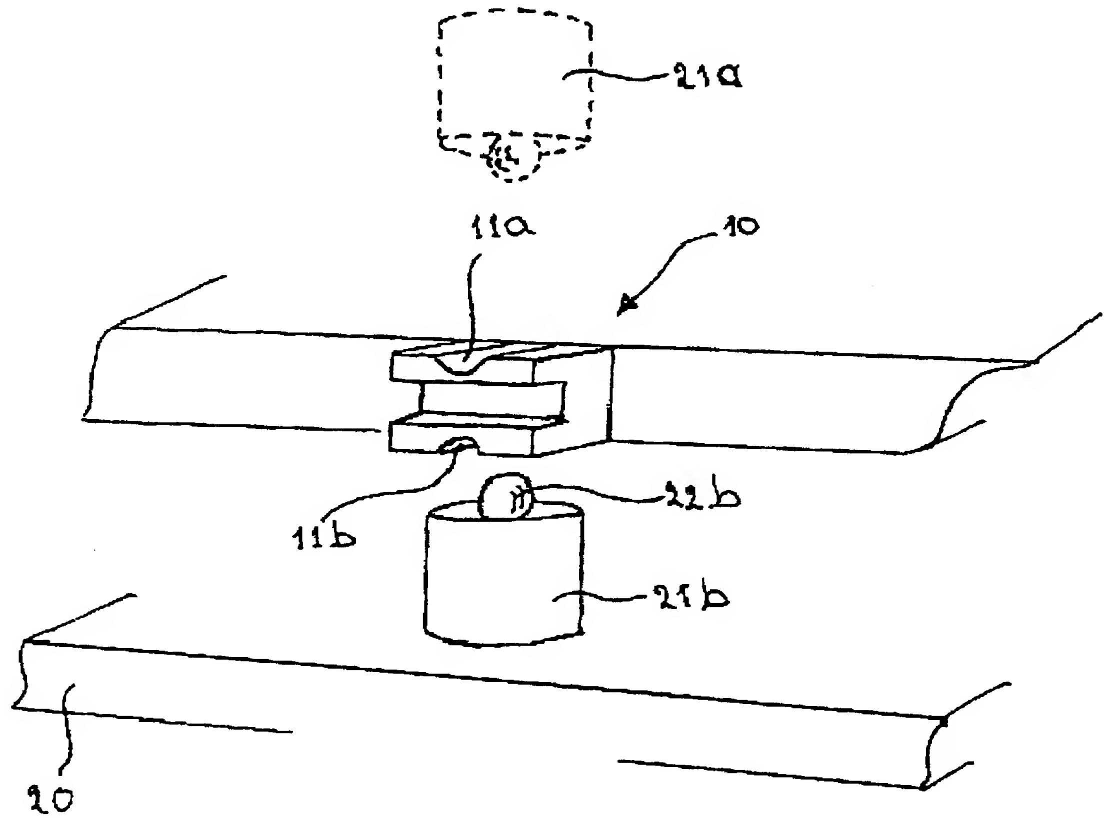

Fig. 3

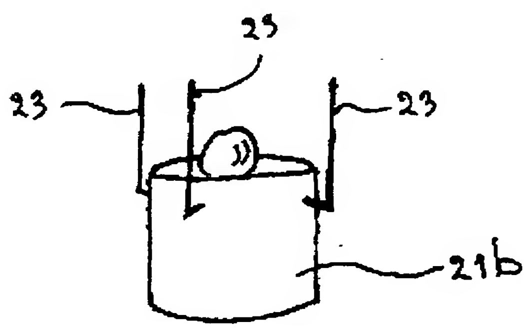

Fig. 4

ABSTRACT

Lithographic Projection mask, and Mask Gripping Device Therefor for use in a Lithographic Projection Apparatus

A mask for use in a lithographic projection apparatus comprises three brackets arranged on the circumference of the mask. The brackets are provided with grooves directed to a common imaginary point and are intend to cooperate with three pins provided on a mask gripping device present in the lithographic apparatus. Preferably, the pins are provided with boll for insertion in associated grooves of the brackets to provide a kinematic mechanical position of the mask on the gripping device.

Fig. 3